On the correlations between air traffic and controller's eye movements

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Abstract—*Air traffic controllers always play an important role in the air transportation system. However, the understanding of the interaction between controllers' cognitive activities and complex traffic activities are less addressed. Many kinds of metrics have been summarized to analyze complex traffic situations. Eye movements are considered to be related to cognitive activities. This paper aims to investigate quantitative correlations between air traffic controller's eye movement activities and traffic activities. Eye-tracking data and flight radar tracks are recorded during real-time simulations. Commonly used eye movement and traffic measures are calculated. Linear or nonlinear correlations between traffic measures and visual measures are profoundly examined based on time series analysis techniques. We assume that there are three types of cognitive activities during the control process, i.e. targets tracking, conflict recognition, and attention allocation. Various combinations between eye movements and traffic activities are identified correspond to the different cognitive behaviors.*

Keywords-air traffic management; eye movements; correlations

I. INTRODUCTION

In the safety-critical systems, such as air traffic management (ATM) system, the behaviors of the operators have direct impact on the system's safety and efficiency. Air traffic controllers are the final decision-maker and executor in the ATM system, and the understanding of their behaviors has been one of the major research issues in the ATM domain.

Given the unique nature of air traffic control work, controller's mental workload has been considered as the main factor that affects the controller's performance, which consequently limits ATM capacity. There are a considerable amount of research work on the study of measuring and predicting the controller's workload [1,2]. By the examination of the controller's routine work, queuing theory was first applied to estimate the controller's workload [3]. Psychologists and cognitive scientists have also developed models to qualitatively describe controller's internal activities [4]. For instance, one of the research work carried out by Histon and Hansman has identified 4 kinds of mechanisms, which controllers use to mitigate their cognitive complexity [5]. However, currently there is no commonly used method to measure and predict controller's workload correctly.

There is another school of research focusing on the other side of the ATM system e.g. air traffic and airspace activities, which aims to understand the factors driving workload [6-8]. One of the widely investigated factors is the complexity, since complexity is seen as the major factor that affects controller's workload. Metrics such as dynamic density, complexity map, etc. are proposed and demonstrated either from operational data or experimental data [9-15], providing insights into the intrinsic characteristics of air traffic. The quantitative relationships between workload and complexity measures are however hardly to be established.

It should be noted that much previous efforts has been devoted to the study of air traffic controller's communications, cognitive activities and mental workload[1,5]. Little attention has been given to their eye movements activities. Most of information obtained is through controllers' visual systems. Based on the integrated information from various sources being displayed on the radar screen, controllers direct flights moving smoothly in the airspace. Even in the next generation of ATM system, most of control work will be done by the automations. A great deal of controller's work will be monitoring all the automations operating functionally. They can take control if there are any failures occurred in the system [16-17]. Therefore, the understanding of controller's eye movements is of great importance to the ATM field.

Although there are a lot of research work on eye movements from various disciplines, including psychology, ergonomics, and computer science etc. [18-23], few work can be found on the analysis of controller's eye movements. In [24], Ahlstrom and Friedman-Berg examined the correlations between controller's eye movements and cognitive workload. It is found that eye movement measures can provide a more sensitive measure of workload as observed in numerous behavioral studies. Recently, MITRE CAASD has carried out an eye-tracking study to evaluate their newly developed automation concept, Relative Position Indicator (RPI) [25]. Wang et. al. analyzed controller's eye movements data and found that two kinds of eye movements patterns among five levels of competence of controllers [26].

In this paper, we present our recent results on the analysis of controller's eye movements and air traffic activities. Real-time simulations were carried out to collect eye movement data and air traffic data. Five measures on eye movements as well as 23 measures on air traffic are calculated with the same sampling rate from the original data sets. Pearson correlation and Spearman's rank correlation are both employed to investigate the relationships between air traffic and controller's eye movements. Initial results and future work are discussed.

II. EXPERIMENTS

To investigate controllers' eye movements, a two-weeks real-time simulations were carried out in the radar simulation lab at Nanjing University of Aeronautics and Astronautics in June, 2015. Experienced controllers from Air Traffic Management Bureau of Jiangsu Province were invited to participate the experiments. Eye movements data were recorded with faceLAB, while traffic data were record by the simulation systems. The detail of the experiments is described as follows.

A. Participants

A total of 16 personnel (15 males, 1 female) aged 22-33 years volunteered to participate in this investigation (see table 1). All of them are qualified controllers responsible for approach control in Nanjing. The minimum working experience is 2 years, while the maximum is 12 years. In China, based on the working experience and personal competency, controllers are qualified into five classes. But there is no Level-1 controller among the volunteers. However, the difference in controllers' levels is out of concern of current study.

TABLE I. THE NUMBER OF CONTROLLERS

	Level-2	Level 3	Level 4	Level 5
Male	2	1	3	9
Female	0	0	1	0

B. Equipment

FaceLAB 5.0 with automatic software was used to record controllers' eye movement. It can provide a very high quality tracking without interfering with the user environment, which has been widely used in commercial, clinical and research applications. The features, such as head-pose, saccades, eye blinks and pupillometry etc, can be measured by this device.

In order to investigate the relationship between eye movements and traffic behaviors under various traffic situations, radar control simulation systems are used to perform high-fidelity simulation exercises. Both the functions and the interface at controller's position are exactly the same as their work station in the ATMB. The radar control simulation system can record the positions of every flight in the radar screen in every 4 seconds. Detailed information of the aircraft such as the latitude, longitude, altitude, speed and heading were retrieved from the system for further analysis.

C. Simulated airspace and traffic scenarios

We select Wuhan Approach Sector for simulated airspace environment. As shown in Fig. 1, the sector ZSHCAP03 is for all the arrival flights and departure flights in Wuhan approach. Departure flow and arrival flow is not separated in the controlled airspace. There are four major traffic flow and a flow over flights.

Four levels of traffic scenarios are prepared based on the real schedule. Every simulation exercise lasts about 20-30 minutes. The difference in traffic scenarios is not considered in current study. In total, we have 32 sets of simulation exercises data to analyze (16 controllers, each has 2 simulation exercises).

The faceLAB cameras were set up in the front of controller's keyboard under the middle of main radar screen. A precise model was built for each participant, and calibration was made before simulation starts. All participants were required to have normal utilization of both arms and legs and permitted to wear eyeglasses for vision correction, as they were doing normal control job. Brief introduction of the purpose of the study and the traffic scenario was given before each simulation run.

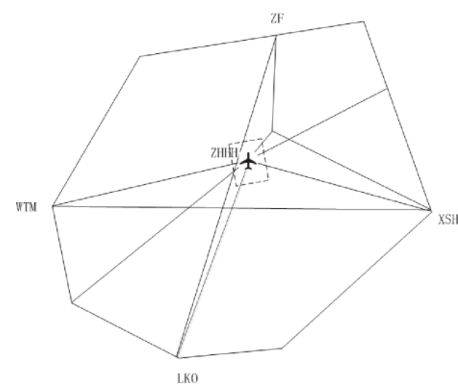


Figure 1. *Airspace structure in Wuhan approach. The main fixes are ZF, WTM, LKO, and XSH. Departure/arrival traffic from/to Wuhan airport are all through these fixes.*

III. DATA PREPARATION

A. Eye movements measures

The determination of fixation and saccadic has to be done before further analysis of eye movements. To extract fixation points from recorded data, we developed an algorithm mainly based on the Velocity-threshold fixation identification (I-VT) algorithm. I-VT algorithm has been widely used in lots of eye-tracking research. Angular velocity is used to distinguish fixation and saccade points. A crucial parameter, the velocity threshold, must be designated in advance, e.g. velocity threshold is set to $120^o / s$. The original time series data is first sorted according to the recorded time. Then, I-VT begins by calculating point-to-point angular velocities for each point. The following rules will be applied to distinguish fixation and saccade points: If the point's angular velocity is less than the threshold, it is identified as fixation point; otherwise it is identified as saccadic point. The process then collapses consecutive fixation points into fixation groups and discards saccade points.

Finally, I-VT outputs each fixation group represented by , where x and y are the center of the points in a group , t represents the time of the first point, and d gives the duration of the fixation group.

Here, we selected 6 eye movements measures for our further analysis, which are the average number of Area of Interest (AOI), average fixation duration, saccadic velocity, mean pupil diameter of left eye, mean pupil diameter of right eye and mean blinking rate. When many fixations appear clustered close together, this might suggest that there are some kinds of stimuli in the proximity of these fixations that attracts attention. These clusters are what could be called areas of interest [27].

B. Traffic metrics

Air traffic complexity has been extensively investigated during the last decades. Research focus has been given on the identification of the quantifiable complexity variables or factors. Building upon the previous work, we select the following 23 traffic-related metrics to describe various traffic behaviors. All these metrics can be calculated from recorded traffic data.

- Number of aircraft.
- Aircraft count divided by the capacity of the sector.
- Total controlled kilometers: the flight distance for all flights under control in the airspace unit.
- Mean controlled kilometers: the average flight distance for all flights under control in the airspace unit.
- Total controlled time: the flight time for all flights under control in the airspace unit.
- Mean controlled time: the average flight time for all flights under control in the airspace unit.
- Number of climbing aircraft.
- Number of cruising aircraft.
- Number of descending aircraft.
- Total climbing time.
- Total cruising time.
- Total descending time.
- Number of aircraft with heading change greater than 15 degrees.
- Number of aircraft with speed change greater than 10 knots.
- Number of aircraft with altitude change greater than 750feet.
- Average velocity of aircraft.
- Number of aircraft with 3-D Euclidean distance between 0-5 nautical miles excluding violations.
- Number of aircraft with 3-D Euclidean distance between 0-8 nautical miles excluding violations.
- Number of aircraft with 3-D Euclidean distance between 0-13 nautical miles excluding violations.
- Minimal horizontal separation.
- Minimal vertical separation.
- Number of potential conflicts.
- Minimal time-to-go to conflict.

C. Pearson Correlation coefficient

Pearson correlation coefficient is used to capture the correlations between controllers' eye movements behaviors and air traffic behaviors. To make the time series data sets comparable, we use 20s as the sampling rate to calculate eye movements metrics and traffic metrics. Let $fe_i^j(t)$ represents the j^{th} eye movement measure value of the i^{th} participant at the t^{th} slot, while $fc_i^k(t)$ represents the k^{th} traffic metric value. T is the number of time slots that are observed in a traffic scenario.

To compute the correlation ρ_i^{jk} between eye movement-traffic behaviors of the i^{th} participant, one can use the following equation

$$\rho_{ij} = \frac{\sum_t (fe_i^j(t) - \overline{fe_i^j(t)})(fc_i^k(t) - \overline{fc_i^k(t)})}{\sqrt{\sum_t (fe_i^j(t) - \overline{fe_i^j(t)})^2} \sqrt{\sum_t (fc_i^k(t) - \overline{fc_i^k(t)})^2}} \tag{1}$$

where $\rho \in [-1,1]$.

D. Spearman's rank correlation coefficient

Spearman's rank correlation coefficient assesses how well the relationship between two variables, which is appropriate for both continuous and discrete variables, including ordinal variables. Spearman's correlation coefficient only considers the ranking of the variables in the time series which is defined as the Pearson correlation coefficient between the ranked variables. Therefore, Spearman's coefficient can be used to evaluate the non-linear correlation between the two time series. Rank the time series x in ascending sort order: $X_i, i \in 1, 2, ..., n$ and then note their locations as $Rankx_{ij}$. $Rankx_{ij}$ represents the location of the element i in the time series j. For the time series Y, $Y_i, i \in 1, 2, ..., n$, the $Ranky_{ij}$ means location of the element i in the time series j. The Spearman's correlation coefficient for time series can be computed as

$$\rho = 1 - \frac{6\sum_{i=1}^{n} d_i}{n^3 - n} \quad (2)$$

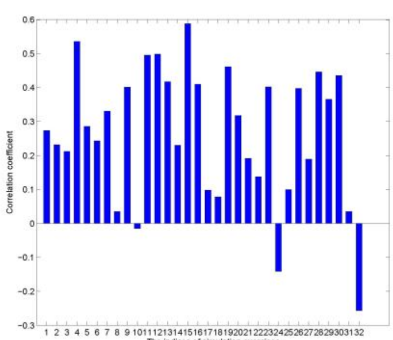
where $d_i = Rankx_{ij} - Ranky_{ij}$ and $\rho \in [-1, 1]$.

IV. RESULTS

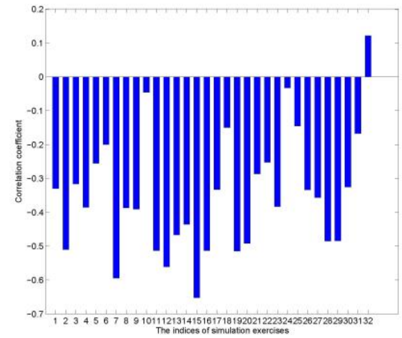
We have calculated all the correlation coefficients (Pearson coefficient & Spearman's coefficient) between eye movements measures and traffic measures, of all the 32 simulation exercises data sets. According to the statistical results and controllers' cognitive process, we focus on three categories of activities: target tracking, conflict recognition and attention allocation.

A. Targets tracking revealed by Pearson's correlations

By the examination of Pearson correlation test between the metrics of controllers' behaviors and traffic behaviors, we found that not all the combinations of controller-traffic behavior have the regular correlation characteristics. We did found one interesting result that one eye movements measure and two traffic metrics are closely correlated for most of controllers (>93%): the average saccadic velocity of controllers is positively correlated with the average velocity of the aircraft within the sector but has a negative correlations with the number of the aircraft. Correlation results are presented in Fig. 2.



(a) *Average saccadic velocity-average velocity.*



(b) *Average saccadic velocity-the number of the aircraft*

Figure 2. *Correlation of selected combinations for all controllers.*

The average saccadic velocity reflects the capability of controllers in dealing with tasks. If there are more aircraft in the sector, there will be more targets to be focused on by the controllers when monitoring the traffic situations; and they have to look at every flight, which will reduce the frequency of the controllers in switching the targets and thus reduces the saccadic velocity. Therefore, the average saccadic velocity is in negative correlation with the number of the aircraft. If the average velocity of the aircraft within the sector becomes faster, the evolution of traffic situation becomes faster. In order to adapt to the changing trend of the object spatially, controllers should also adjust the personal behaviors and improve the speed of monitoring targets. Therefore, the average saccadic velocity is positively correlated with the average velocity of the aircraft.

There is no expected regularity discovered among other eye movements-traffic behavior metrics, and some individuals even have significant difference. For instance, the number of AOIs and the number of aircraft is expected to be in positive correlation. When there are more aircraft in the sector, the traffic density in a given volume of airspace increases, and the number of AOIs therefore will also increases. Statistical results indicate that the number of AOIs and the number of aircraft has negative relationship for about 33% controllers while positive relationship for the other 67% controllers.

The statistical results show the obvious linear correlations during the target tracking activity. In order to further investigate the other type of correlation between traffic activities and eye movement activities, we will conduct an in-depth analysis of Spearman's rank correlations of all the combinations.

B. Spearman's rank correlation analysis results

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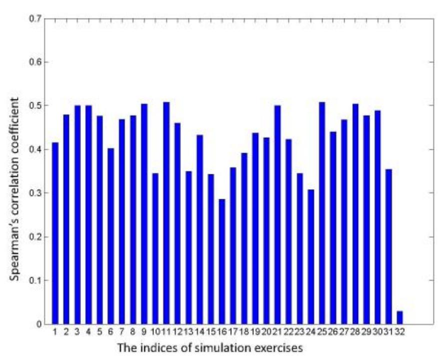
By comparing the analysis results with Pearson correlation, it is found that there do exist non-linear correlations between more eye movements metrics and traffic complexity metrics combinations.

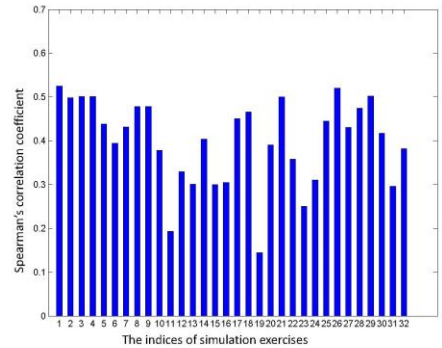
In the field of target tracking, Spearman's rank correlation presents a similar pattern from the same activity combinations. So we will provide a detailed description of correlations from the rest two aspects: conflict recognition and attention allocation.

1) Conflict recognition

In order to ensure the safety of air traffic, it is critical to identify and resolve the potential conflicts in the airspace. As shown in Fig. 3a, average fixation duration is positively correlated with the number of aircraft pairs with 3-D Euclidean distance between 0-5 nautical miles. In our simulations, a minimum of 10km should be maintained between any aircraft pairs. If there are more aircraft pairs with separation less than 5 nautical miles, there will be more potential conflicts in the sector. To resolve the potential conflicts, controllers will pay more attention to related aircraft. Fig. 3b also shows the positive correlation between the number of AOIs and the number of aircraft pairs with 3-D Euclidean distance between 0-5 nautical miles. When the number of the aircraft with separation less than 5 nautical miles increases, the difficulty for conflict resolution will also increase. Therefore, it is necessary to gather more information to resolve the conflict. And controllers will pay more attention to more AOIs. Compared with Pearson correlation analysis results, these two combinations exhibit the complete positive correlation trend. In spite of individual difference, all controllers behave similarly under different experiments. It can be drawn from the results here, owing to the structure of sector, conflict type and working skill, traffic activities have a non-linear effect on controllers' eye movements.



(a) Average fixation duration-the number of aircraft pairs with 3-D Euclidean distance between 0-5 nautical miles.

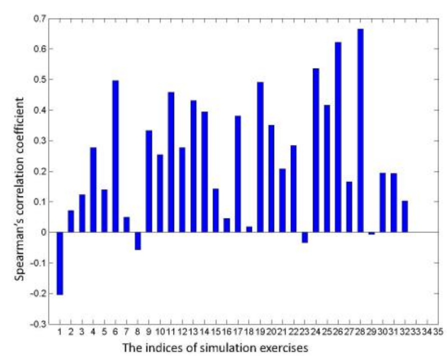


(b) The number of AOIs-the number of aircraft pairs with 3-D Euclidean distance between 0-5 nautical miles

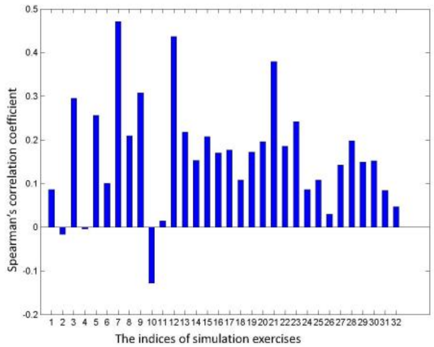
Figure 3. *Spearman Correlation of selected combinations for all controllers.*

2) Attention allocation

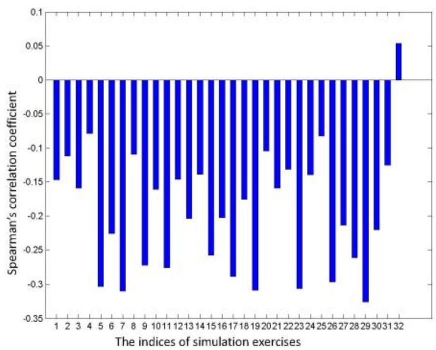
Air traffic controllers' eye movement metrics indicate the distributions of their attention. As shown in Fig. 4a and Fig. 4b, both pupil diameter and average fixation duration are positively correlated with controlled time. Whereas Fig. 4c shows that the saccadic velocity is negatively correlated with controlled time. Fatigue can directly result in the dilation of left/right eye pupil. When the controlled time increases, controllers are more likely to feel tired and cannot be able to concentrate on the work. Therefore, the saccadic velocity will slow down, and average fixation duration will increase. These results can be explained as the unreasonable allocation of attention. Consequently, controllers cannot handle the emergency situation in time, which will increase the potential risk in the sector.



(a) Left/right eye pupil diameter-controlled time.



(b) Average fixation duration-controlled time.



(c) Saccadic velocity-controlled time.

Figure 4. *Spearman Correlation of selected combinations for all controllers.*

V. CONCLUSIONS

In this work, the analytical results on the correlations between controllers' eye movements and air traffic activities are presented. The relationships between eye movements and traffic activities are tested based on Pearson correlations and Spearman's rank correlations. We assume that there are three types of cognitive activities during the control process, i.e. targets tracking, conflict recognition, and attention allocation. For each of these activities corresponding combinations of traffic metrics and eye movement metrics are identified. The analysis results also offer a quantitative understanding of interactions between different behaviors. Further efforts should be given to investigate these three types of correlated measures which may contribute to our deep understanding of human factors in the air transportation field.

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REFERENCES

[1] S. Loft, P. Sanderson, A. Neal, and M. Mooij, “Modeling and predictingmental workload in en route air traffic control: Critical review andbroader implications,” Human Factors, vol. 49, no. 3, pp. 376–399, 2007.

[2] C. Manning, S. H. Mills, C. M. Fox, E. M. Pfleiderer, and H. J. Mogilka,“Using air traffic control taskload measures and communication events to predict subjective workload,” Federal Aviation Administration, Tech. Rep. DOT/FAA/AM-02/4, 2002.

[3] D. K. Schmidt, “A queuing analysis of the air traffic controller’s work load,” IEEE TRANSACTIONS ON Systems Man and Cybernetics, vol. SMC-8, no. 6, pp. 492 – 498, 1978.

[4] B. Hilburn, “Cognitive complexity in air traffic control ?literature review,” Eurocontrol, Tech. Rep. EEC Note No.04/04, 2004.

[5] J. M. Histon and R. J. Hansman Jr, “Mitigating complexity in air traffic control: the role of structure-based abstractions,” ICAT, Tech. Rep. ICAT-2008-05, 2008.

[6] P. Averty, C. Collet, A. Dittmar, S. Athenes, and E. Vernet-Maury, “Mental workload in air traffic control - an index constructed from field tests,” Aviation, Space, and Environmental Medicine., vol. Vol. 75, no. 4, pp. 333-341. Apr. 2004, 2004.

[7] G. L. Yousefi, Arash; Donohue, “Temporal and spatial distribution of airspace complexity for air traffic controller workload-based sectorization,” AIAA 4th Aviation Technology, Integration and Operations (ATIO) Forum; Chicago, IL; USA; 20-22 Sept. 2004., pp. pp. 1–14. 2004, 2004.

[8] A. Majumdar and W. Y. Ochieng, “Air traffic control complexity and safety: Framework for sector design based on controller interviews of complexity factors,” Transportation Research Record., p. 10, 2007.

[9] I. V. Laudeman, S. Shelden, R. Branstrom, and C. L. Brasil, “Dynamic density: An air traffic management metric,” National Aeronautics and Space Administration, Ames Research Center;, Tech. Rep. NASA/TM-1998-112226, 1998.

[10] B. Sridhar, K. S. Sheth, and S. Grabbe, “Airspace complexity and its application in air traffic management,” in 2nd USA/Europe Air Traffic Management R&D Seminar, 1998, pp. 1–6, 2 ndUSA/Europe Air Traffic Management R&D Seminar.

[11] A. J. Masalonis, M. B. Callaham, and C. R. Wanke, “Dynamic density and complexity metrics for realtime traffic flow management,” in 5th USA/Europe ATM R&D Seminar, 2003, pp. 23–28, 5th USA/Europe Air Traffic Management Research and Development Seminar.

[12] D. Baart, “An evaluation of dynamic density metrics using rams,” 2001, FAA report.

[13] D. Delahaye, S. Puechmorel, R. J. Hansman Jr, and J. Histon, “Air traffic complexity map based on non linear dynamical systems,” Air Traffic Control Quarterly, vol. 12, no. 4, 2004.

[14] D. Delahaye and S. Puechmorel, “Air traffic complexity based on dynamical systems,” in 49th IEEE Conference on Decision and Control (CDC), 2010, pp. 2069–2074.

[15] K. Lee, E. Feron, and A. Pritchett, “Air traffic complexity: An inputoutput approach,” in American Control Conference, 2007. ACC’07, 2007, pp. 474–479.

[16] C. Hasse, D. Grasshoff, and C. Bruder, "Eye-tracking parameters as a predictor of human performance in the detection of automation failures," in Human Factors: a view from an integrative perspective, 2012.

[17] T. Prevot, N. Smith, E. Palmer, T. Callantine, P. Lee, J. Mercer, J. Homola, L. Martin, C. Brasil, and C. Cabrall, "An overview of current capabilities and research activities in the airspace operations laboratory at nasa ames research center," in 14th AIAA Aviation Technology, Integration, and Operations Conference (ATIO), 2014.

[18] E. Kowler, "Eye movements: The past 25 years," Vision Research, vol. 51, no. 13, pp. 1457 – 1483, 2011, vision Research 50th Anniversary Issue: Part 2. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0042698910005924

[19] L. K. McIntire, R. A. McKinley, C. Goodyear, and J. P. McIntire, "Detection of vigilance performance using eye blinks," Applied Ergonomics, vol. 45, no. 2, Part B, pp. 354 – 362, 2014. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0003687013000938

[20] L. L. D. Stasi, A. Catena, J. J. C. nas, S. L. Macknik, and S. Martinez-Conde, "Saccadic velocity as an arousal index in naturalistic tasks," Neuroscience & Biobehavioral Reviews, vol. 37, no. 5, pp. 968 – 975, 2013. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0149763413000717

[21] J. G. May, R. S. Kennedy, M. C. Williams, W. P. Dunlap, and J. R. Brannan, "Eye movement indices of mental workload," Acta Psychologica, vol. 75, no. 1, pp. 75 – 89, 1990. [Online]. Available: http://www.sciencedirect.com/science/article/pii/000169189090067P

[22] J. S. Ha and P. H. Seong, "Experimental investigation between attentional-resource effectiveness and perception and diagnosis in nuclear power plants," Nuclear Engineering and Design, vol. 278, no. 0, pp. 758 – 772, 2014. [Online]. Available: http: //www.sciencedirect.com/science/article/pii/S0029549314004956

[23] R. J. Jacob and K. S. Karn, "Commentary on section 4 – eye tracking in human-computer interaction and usability research: Ready to deliver the promises," in The Mind's Eye, J. Hy ̈on ̈a, R. Radach, and H. Deubel, Eds. Amsterdam: North-Holland, 2003, pp. 573 –605. [Online]. Available: http://www.sciencedirect.com/science/article/pii/B978044451020450031 1

[24] U. Ahlstrom and F. J. Friedman-Berg, "Using eye movement activity as a correlate of cognitive workload," International Journal of Industrial Ergonomics, vol. 36, no. 7, pp. 623 – 636, 2006. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0169814106000771

[25] J. P. Shepley, J. Sanchez, C. M. Johnson, and E. Smith, "Eye-tracking analysis of near-term terminal automation for arrival coordination," in 9th AIAA Aviation Technology, Integration, and Operations Conference (ATIO), 2009.

[26] Y. J.Wang, W. Cong, B. Dong, F. Wu, and M. M. Hu, "Statistical analysis of air traffic controllers eye movements," in The 11th USA/Europe ATM R&D Seminar, 2015.

[27] Hedberg B. Areas of Interest in Eye Movement Data. Lund University, 2000.